PROCEEDINGS
OF THE
NATIONAL ACADEMY OF SCIENCES
Volume 18 October 15, 1932 Number 10

THE FORAMINIFERAL GENUS ORBITOLINA IN GUATEMALA AND VENEZUELA

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Communicated August 17, 1932

At the end of January, 1930, Dr. C. A. Matley brought to me specimens of a species of *Orbitolina* collected by him in a hard, bluish limestone in the vicinity of Guatemala City, and Dr. L. W. Stephenson has submitted collections from Venezuela.

The number of names proposed for the American species of the genus is relatively small. They are as follows:

Orbitulites texanus Roemer (1849, p. 392; 1852, p. 86, pl. 10, figs. 7a–d) (= *Orbitolina texana* (Roemer) of subsequent authors).

Orbitulina venezuelana Karsten (1866, pl. 6, fig. 6) (= *Orbitolina venezuelana* (Karsten) of subsequent authors).

Orbitolina whitneyi Carsey (1926, p. 22, pl. 6, figs. 9a–b).

Orbitolina walnutensis Carsey (1926, p. 23, pl. 7, figs. 11a–b).

Orbitolina texana asaguana Hodson (1926, p. 5, pl. 1, figs. 6, 8).

Orbitolina texana monagasa Hodson (1926, p. 5, pl. 1, figs. 7, 9).

Orbitolina thompsoni Hodson (1926, p. 5, pl. 1, figs. 1, 5).

Of the forms listed above, every one of them except *O. venezuelana* (Karsten) is represented by material, including thin sections in the collections of the Scripps Institution. *O. venezuelana* (Karsten) was based on small conico-capuliform specimens about 3 mm. in diameter. I have been able to match Karsten's figures by picking out small specimens of *O. texana* (Roemer). Therefore, *O. venezuelana*, 1866, may be a synonym of *O. texana*, 1849.

Silvestri (1932, p. 177) mentions a paper by Dietrich (1924) which deals with Venezuelan species of *Orbitolina*. Besides *O. venezuelana*, Dietrich mentions *O. lenticularis* (Blumenbach), a species which ranges in the European Cretaceous from the Barremian to the Albian. I have not seen Dietrich's paper, but it would not affect the present note.

Orbitolina texana (Roemer) is very abundant in the Glen Rose formation of Texas. *O. whitneyi* Carsey is only a large-sized variant of it. Mrs.

Hodson's two subspecies of *O. texana* and her *O. thompsoni* are only growth forms of *O. texana*. The four forms of *Orbitolina* to which she applies names all occur at the same locality on Rio Asagua, State of Monagas, Venezuela.

O. walnutensis Carsey differs so greatly from the other species that it may belong to another genus.

Dr. L. W. Stephenson has sent me Venezuelan material from the following localities:

State of Zulia, Island of Taos, in massive limestone forming the westernmost point of the island. Collected by L. W. Stephenson, J. A. Tong and G. D. Hawkins, Oct. 15, 1923, Venezuela Gulf Oil Co. acq. no. 63.

State of Trujillo, Lower Cretaceous limestone, near the Mendoza Road, 4 kms. S. 35° W. of Valera, about 1 km. S. W. of a sugar-cane mill. Collected by L. W. Stephenson and J. A. Tong, Jan. 1, 1924, Venezuela Gulf Oil Co. acq. no. 158.

State of Anzoategui, loose limestone in the road to Barcelona, 0.8 km. S. W. of Bergantin. Collected by L. W. Stephenson and W. H. Butt.

The same species of *Orbitolina* occurs at all these localities. Three of the forms designated by Mrs. Hudson, viz., *O. texana*, *O. texana asaguana* and *O. texana monagasa* are recognizable.

The species collected by Doctor Matley near Guatemala City is the same as that obtained by Doctor Stephenson in Venezuela. It is very close to, if not identical with, *O. texana*.

The *Orbitolina*-bearing limestones of Guatemala and Venezuela are correlated with a part of the Texas Lower Cretaceous, Comanche Series, approximately the Glen Rose horizon.

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CRETACEOUS ORBITOIDAL FORAMINIFERA FROM THE GULF STATES AND CENTRAL AMERICA

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Communicated August 17, 1932

Introduction.—This paper gives an account of two collections submitted to the senior author for determination. The first of these collections is from Misterfeldt Well Number 1, depth 3480–91 feet, Rankin County, Mississippi. The material was received from Mr. R. D. Norton of the Texas Company and Mr. Stephen Rook of the Gulf Refining Company of Louisiana.

The second collection is a core from Welch Well Number 1, depth 4167–72 feet, of the Evansville Investment Company, Section 2, Township 14 N., Range 8 E., Franklin Parish, Louisiana, sent to the senior author by Mr. Merle C. Israelsky of the Louisiana Gas and Fuel Company. In connection with this collection we have received from Mr. F. W. Rolshausen of the Humble Oil and Refining Company material obtained from wells in Uvalde and Zavalla Counties and from surface exposures in McKinney County, Texas. We are associating with this material specimens collected in Southern Petén, Guatemala, by Dr. Hakon Wadell.

Genus ASTERORBIS Vaughan and Cole, n. gen.

Genoholotype: Asterorbis rooki Vaughan and Cole

Since this genus is based on the species described below, only comments are needed here. *Asterorbis* is very similar to *Orbitocyclina* Vaughan (1929), except that the test is stellate instead of being subcircular in outline. Since it seems to bear the same relation to *Orbitocyclina* that *Asterocyclina* bears to *Discocyclina*, later it may be found preferable to consider it a subgenus of *Orbitocyclina*, rather than to accord it generic rank. It is our present purpose to emphasize the occurrence of a new type of orbitoid in the Upper Cretaceous of the Gulf Coastal Plain, rather than to decide what taxonomic rating it should receive.

Test small, lenticular, conspicuously stellate, central region raised, umbonate, from which five raised ribs radiate, increasing gradually in width as they approach the peripheral angles. Entire surface covered with small papillae, larger on the umbo. The smallest specimen measured has a diameter of 0.62 mm. and a thickness of 0.25 mm.; the largest, a diameter of 4.5 mm. and a thickness of 0.6 mm. Average specimens have a diameter of about 2.90 mm. and a thickness of about 0.74 mm. Equatorial sections indicate the stellate shape.

Embryonic apparatus poorly preserved. As far as can be told from the sections, it is composed of two subequal chambers, with one or more supplementary chambers. The two main chambers are surrounded by a relatively thick wall. The initial subspherical chamber is about 135 μ in diameter; the diameter of both chambers measured in a line through the center of the initial chamber is about 210 μ. There is between the chambers an opening which has a diameter of about 38 μ, but it may have been caused by breakage. The principal supplementary chamber has a length of 127 μ and a width of 38 μ. The wall surrounding the initial chamber is about 15 μ in thickness.

In horizontal section the equatorial chambers are either diamond shaped or their outer walls may be curved and the inner ends pointed or truncate. The chambers gradually increase in size as they approach the periphery. Near the center, radial diameter, 30 μ, transverse diameter, 45 μ. Near the periphery, radial diameter about 45 μ, transverse diameter about 92 μ.

In vertical sections the equatorial chambers increase gradually in height from the center to the periphery. Between the rays, the height at the center is about 37 μ, at the periphery, about 165 μ. In sections along the rays there is a very rapid increase in height toward the periphery. In some sections, the ends of the rays present a bulb-like cross-section composed entirely of thickened equatorial chambers, which in such places may attain a height of 217 μ.

The lateral chambers as seen in vertical sections form definite tiers. The number of layers in the thick umbonate area is as many as 16 on each side of the equatorial layer. Outside the umbonate area the number decreases until at the actual edge there are none, the equatorial layer being without cover. This condition is especially noticeable in sections cut along the rays. The chamber cavities are about 15 μ in height and 75 μ in length. The roofs range between 6 and 10 μ in thickness. Pillars are formed by thickened, alternating ends of chamber roofs and are well developed, especially in the center of the test where they have a diameter of about 52 μ.

DESCRIPTION OF PLATE 1

Asterorbis rooki Vaughan and Cole, new gen. and sp. All figures, × 28.

Figure 1, horizontal section passing through embryonic and equatorial chambers of a pentagonal specimen. Figure 2, a part of a horizontal section through embryonic chambers. Figure 3, an oblique section passing through the embryonic chambers. Figure 4, an oblique section passing through a part of the equatorial plane. Figure 5, vertical section of several specimens. Note the greatly thickened equatorial chambers in the peripheral part of the specimen on the right-hand side of the figure. Figure 6, vertical section of several specimens. Note the thickened equatorial chambers at the periphery of the specimen on the right-hand side.

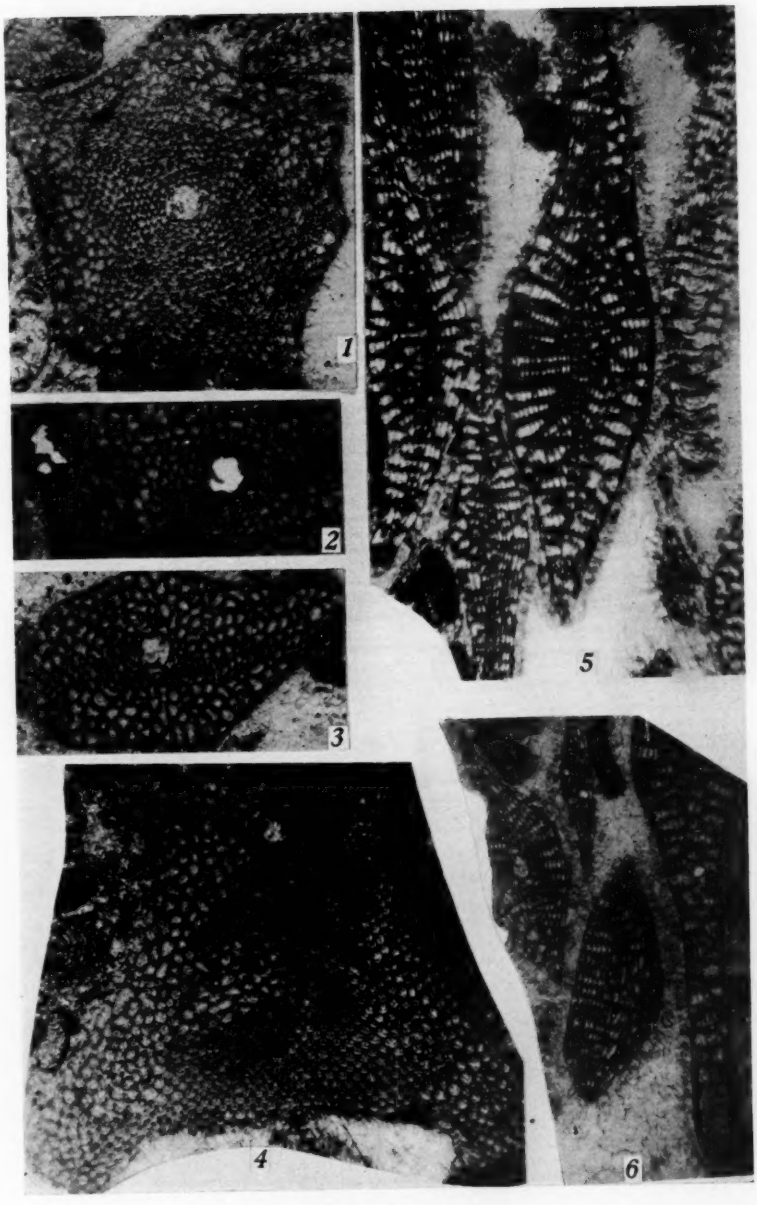

PLATE 1. (Description on opposite page.)

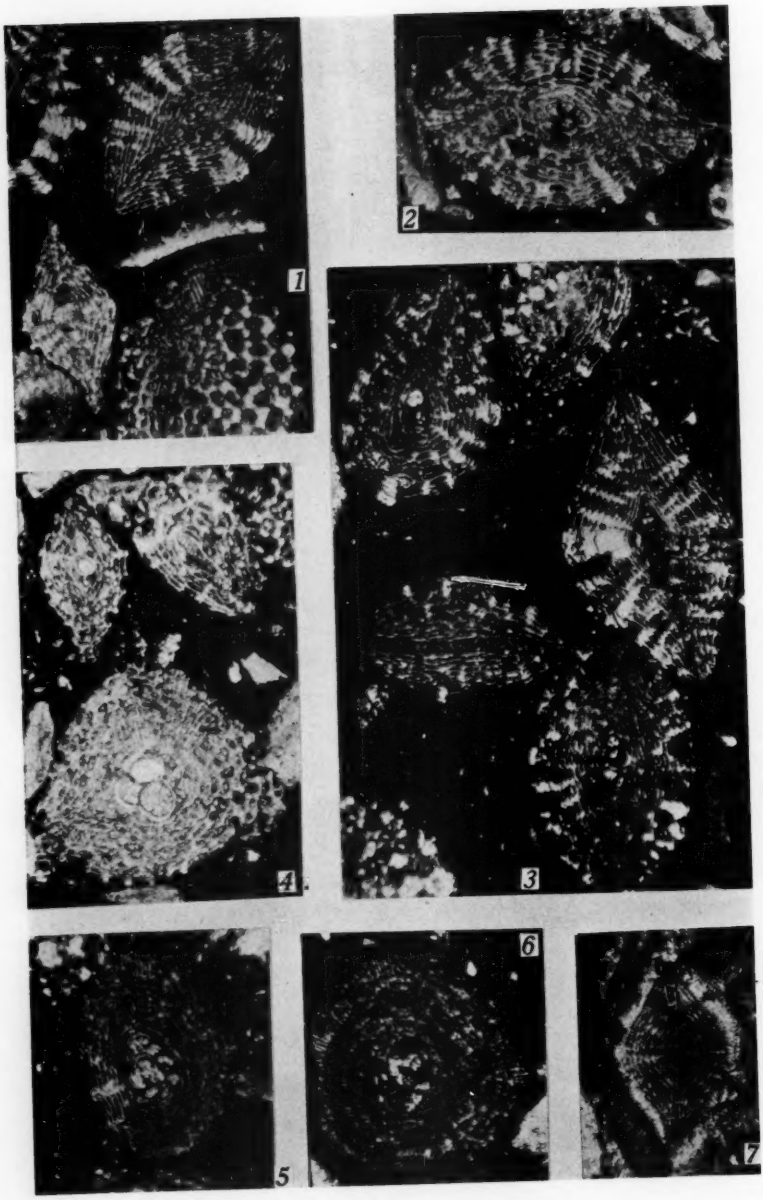

PLATE 2. (Description on opposite page.)

Geologic Horizon and Locality.—Upper Cretaceous, Misterfeldt Well No. 1, depth 3480–3491 ft., Sec. 2, T. 4N., R. 1E., Rankin County, Mississippi.

Under date of October 12, 1929, Mr. R. D. Norton wrote as follows:

"I am sending you two additional samples from the core of the Misterfeldt No. 1 at 3480–91 feet. The smaller piece has a couple of possible horizontal sections, and the larger portion should give you some good vertical sections. In regard to the stratigraphy of this well: the base of the marine Claiborne is about 1450 feet, and Midway shales are present just below 2900 feet. The top of a limestone is logged by the drillers at 3065 feet. I think this is also of Midway age. The series from 3142 to 3460 feet is practically all logged as chalk. No cores were obtained between these depths. The lithology of the core from 3480–91 feet suggests that of the 'Monroe Gas Rock' of Louisiana. I am inclined to believe that the top of the Upper Cretaceous in this well is close to 3142 feet, and that the stratigraphic position of the above core is close to that of the material I sent you from the Texas Company, Huff No. 1, in Morehouse Parish, Louisiana."

The well in Morehouse Parish, referred to by Mr. Norton, is the type locality of *Orbitocyclina nortoni* Vaughan (Vaughan, 1929). Vaughan, in his paper referred to, mentions the occurrence of a species of *Hamulus* with *O. nortoni*. *Hamulus* sp. indet. is also present in the same piece of rock that contains *Asterorbis rooki*. In fact, there is associated with *A. rooki* a thin species of discoidal orbitoid. Of this form the diameters of two specimens are, respectively, 1.9 and 4.23 mm. The embryonic and the equatorial chambers are similar in form and size to those of *Orbitocyclina nortoni*. There are about eight layers of lateral chambers on each side of the equatorial plane over the center. The specimens may be confidently identified as that species. Therefore, it and *Asterorbis rooki* occur together.

Although the horizon, at which the two species above noted occur, is definitely Upper Cretaceous, it is not practicable for us to refer them to one of the named geologic formations.

DESCRIPTION OF PLATE 2

Pseudorbitoides israelskii Vaughan and Cole, n. sp. All figures, × 28.

Figures 1–6, material from Evansville Investment Company, Welch Well No. 1, depth 4067–72 ft., Sec. 2, Township 14 N., Range 8 E., Franklin Parish, Louisiana. Figure 1, vertical sections of two specimens and an oblique section through lateral chambers and pillars of another specimen. Figure 2, vertical section of a single specimen. Figure 3, vertical sections of 4 specimens. Figure 4, vertical section of one specimen, oblique section of a second specimen and a nearly horizontal section through the embryonic chambers of a third specimen. Figure 5, oblique section through the embryonic chambers. Figure 6, nearly equatorial section showing radiating lines mentioned in the description. Figure 7, vertical section of a specimen in limestone from Southern Petén, Guatemala.

Genus PSEUDORBITOIDES H. Douvillé

Genoholotype.—Pseudorbitoides trechmanni H. Douvillé

Pseudorbitoides H. Douvillé (1922, p. 203; 1923, p. 369, figs. 1, 2); Vaughan, 1929, p. 168, pl. 21, figs. 4–60)

Test small, robustly lenticular. The macrospheric form has a diameter of 0.5 to 1.6 mm.; thickness about one-half the diameter, from 0.27 to 0.9 mm. Surface with a few strong papillae produced by the emergent distal ends of the pillars, which on the surface have a diameter of about 130 μ.

The embryonic apparatus consists of a large subspherical initial chamber, which has a length ranging from 100 μ to as much as 180 μ; the width is only slightly less than the length. The initial chamber is followed by a slightly smaller chamber which has a length ranging from 90 to 180 μ and a width ranging from 80 to 130 μ. These two chambers are connected by an opening about 20 μ in diameter. These two chambers are followed by two or more smaller chambers, the entire mass of chambers forming an irregular spiral. The walls of the embryonic chambers are relatively thick and perforate, the average thickness being about 20 μ.

The equatorial chambers are irregular in shape. In general, they are polygonal, the radial diameter about half the transverse. Some of the chambers exhibit a rude, hexagonal outline, with a tendency to form radiating rows. Their transverse diameter ranges from 60 to 100 μ, and their radial diameter from 30 to 50 μ. They increase in size as they approach the periphery. The intervening walls are thick, ranging from 15 to 25 μ. The thickness of the equatorial layer at the center is about 50 μ, at the point where it becomes double, about 75 μ, and at the periphery, about 100 μ. From the embryonic apparatus to the point where the equatorial chambers become double it is 0.45 mm. The chambers are double through a distance of 0.25 mm. Fine, radiating lines, which are especially prominent near the periphery, are present above the chambers in equatorial sections. These lines occur near the bounding walls of the chambers and above the chamber cavities. The lateral chambers occur in regular tiers, with open, large chamber cavities. There are about 12 layers to a tier on each side of the equatorial layer in the central region. Their number decreases regularly until at the actual edge there are only about 2 on each side of the equatorial layer. Near the periphery in the central area their length is about 100 μ, their height about 30 μ, their roofs and floors about 8 μ in thickness. Between the ends of the lateral chambers there are thick, gradually tapering pillars.

Localities and Geologic Horizon.—The type specimens come from Welch Well No. 1 of the Evansville Investment Company, Sec. 2, T 14 N., R. 8 E., Franklin Parish, Louisiana, depth between 4167 and 4172 ft., Upper Cretaceous.

Under date of January 7, 1931, a letter was received from Mr. F. W. Rolshausen of the Humble Oil Refining Company, Houston, Texas, from which the following paragraphs are quoted:

"I am sending to you, under separate cover, some orbitoid foraminifera from the Taylor formation, Upper Cretaceous, of Texas. The foraminifera were picked from material secured from the Texas Gas Utilities Well No. 2, Pryor, Zavalla County, Texas, depths 1963, 2022–26 and 2026–29. With these foraminifera I am also enclosing some surface material which was secured from the Upson Clay formation in Kinney County, Texas, one-half mile south of the Southern Pacific Railroad, on Elm Creek. I believe the orbitoids noted in the surface samples are the same as those found in the wells."

Pseudorbitoides israelskii occurs both in the wells as indicated above and in the surface exposure.

Mr. Rolshausen also sent perfect specimens from the Anacacho limestone encountered in the Humble Oil and Refining Company's well, Kincaid No. 4, Uvalde Company, Texas. The depth from which the specimens were taken was not stated.

A third region in which the same species is found is Southern Petén, Guatemala, where specimens were collected by Dr. Hakon Wadell in an indurated limestone. A vertical section of a specimen from this locality is illustrated by plate 2, figure 7. Other foraminifera in the same rock comprise a species of *Cuncolina*, which closely resembles *C. conica* d'Orbigny (cf. Schlumberger, 1899, p. 461, pl. 8, figs. 6–10) from the Senonian of Spain and Ile Madame. There is also an Aveolinid species which may belong to the genus *Lacazina*, an associate of *Cuneolina conica*. There is in the Petén rock species representing the Camerinidae and probably the Rotaliidae, but they are scarcely identifiable. There are in the same rock, in addition to the foraminifera above noted, specimens of gastropods of the genus *Actaeonella* and of a rudistid pelecypod, probably a species of *Caprina*.

The type species of the genus *Pseudorbitoides* (*P. trechmanni* H. Douvillé) was collected by C. T. Trechmann (1924, p. 392, table) in Cretaceous limestone in Jamaica at several localities, where it associated with the Jamaica Upper Cretaceous Rudistid and coral fauna. Although the fauna in Southern Petén is small, the assemblage resembles that of Jamaica, and the above-mentioned Senonian fauna of Spain and Ile Madame.

Pseudorbitoides israelskii may be the megalospheric form of *P. trechmanni*, but the two forms have not to our knowledge been found together. Unless they are known to be associated, the same name should not be applied to both.

The principal reason for the interest of geologists in *Pseudorbitoides israelskii* is the aid that it renders geologic correlation. The same species

is found in a deep well in Louisiana, in wells in Zavalla and Uvalde Counties and at the surface in Kinney Country, Texas, and at the surface in Southern Petén, Guatemala. The horizon is in the lower part of the Taylor marl and the stratigraphically equivalent lower part of the Anacacho formation, as those formations are developed in Texas. The most recent interpretation of the Upper Cretaceous stratigraphy in the western part of the Coastal Plain of Texas is by L. W. Stephenson (Stephenson, 1931).

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STRUCTURE AND CORRELATION OF METAMORPHIC ROCKS IN SOUTHEASTERN NEW YORK

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Communicated September 15, 1932

Introduction.—The geology of southeastern New York is known as a complicated part of Appalachian geology. Indirectly connected with the old Taconian problem is the question of the geologic age of the metamorphic rocks which outcrop between the valleys of the Hudson and Housatonic Rivers. The geology of New York City is intimately connected with this problem, because most of the rocks in question outcrop within the confines of the city.

The correlation of these rocks is based on field work by J. D. Dana who, between 1872 and 1890, published his results in a number of papers in the American Journal of Science.[1] Subsequently, the metamorphic belt in southeastern New York was investigated by F. J. H. Merrill, but un-

fortunately he has published little more than 40 pages on the work of many years.[2] Dana and Merrill adopted the older classification by Mather[3] who regarded the metamorphic sediments equivalents of the fossiliferous Cambro-Ordovician sequence northwest of the Hudson Highlands. Charles P. Berkey, as consulting geologist for the Catskill aqueduct of New York City, had an opportunity to examine the entire geological profile from Newburgh and Beacon southward along the Hudson through the Highlands, and on through Westchester County. It happens that near Peekskill, on the east side of the Hudson, two belts of these sediments approach one another very closely; while the one is very little metamorphosed, the other one, less than 2 miles away at the nearest point, contains a highly metamorphic injected schist, in places resembling an injection gneiss. And there are many other dissimilarities between the two belts so that, in 1907, C. P. Berkey expressed doubt in the older correlation, and tentatively regarded the highly metamorphic series as pre-Cambrian.[4] He discussed the matter more fully in 1919,[5] and again inclined to correlate the rocks in question with pre-Cambrian sediments. At the same time, he clearly recognized that the problem cannot be solved within the area through which the aqueduct runs, "but that it probably can be solved by a careful roundabout study of adjacent territory carried through for this particular purpose" (p. 130).

The present article gives a summary of results of such a study. As the structural geology of the region is most interesting, the field work has been done in considerable detail. Over 250 days were spent in mapping the structural geology of the Clove and Carmel quadrangles, and parts of adjacent sheets in southeastern New York and western Connecticut. A detailed discussion of the facts, accompanied by a large illustrative material, is in preparation. As stated in this abstract, the field evidence strongly supports the older correlation which sees in the metamorphic sediments the equivalents of Cambro-Ordovician strata.

Readers who should miss the circumstantial evidence for certain statements in the present article will find it in the forthcoming report. The field and laboratory work has been carried out at the writer's expense.

General Geology of Southeastern New York.—The Highlands of the Hudson, as is well known, are a block of pre-Cambrian gneisses, about 15 miles wide. The Highlands trend northeast-southwest, cross the Hudson between the towns of Beacon and Peekskill, and taper out some 20 miles northeast of the river; see figure 1. Six miles northeast of the point of disappearance, there arises another block of pre-Cambrian gneisses, continuing the same northeastern trend. This upland may be called the Housatonic Highlands, with reference to the principal superposed stream.[6]

To the northwest of this Hudson-Housatonic axis, there are two smaller blocks of pre-Cambrian rocks: a narrow but long one north of Fishkill,

FIGURE 1

Outline map of the region east of the Hudson Highlands, southeastern New York. The pre-Cambrian gneiss (subparallel lines, widely spaced) is surrounded by the lower Cambrian Poughquag quartzite (black); U represents exposed unconformities. Marble (white) and schist (gray, contorted lines) of early Paleozoic age follow to the north, and are in dynamic contact with the gneiss on the east and southeast. The double funnel of the Peekskill norite, and the Croton Falls hornblendite sill are intruded into the schist. The dotted area, four miles east of Peekskill is the Peekskill (Mohegan) granite, which is younger than the Peekskill norite.

and one northwest of Lagrangeville (half way between Clove Valley and Poughkeepsie). Beyond the northern boundary of the map, there is a third, larger uplift, Stissing Mountain (Millbrook quadrangle, N. Y.). These three uplifted blocks are lined up along a zone of north-northeasterly trend.

To the southeast of the Highland axis, conditions are more complicated. While the Hudson block has a sharp topographic and geologic boundary on the northwest, it lacks any definite geological boundary on the southeast side. Instead, an extension of the gneiss branches off to the east, and this is followed by additional blocks of gneiss farther to the southeast.

The space between the pre-Cambrian blocks is occupied, to the northwest of the Highland axis, by fossiliferous Cambrian and Ordovician sediments (Lower Cambrian Poughquag quartzite; Cambro-Ordovician Wappinger limestone and dolomite; Hudson River slate, locally perhaps involved with older slates), and on the southeast side by metamorphic sediments which have never furnished any fossils (basal Lowerre quartzite; Inwood marble; Manhattan schist). Structure and correlation of these rocks present the subject of this article.

The Structural Problem.—It was pointed out in the foregoing that there is a gap between the northeast end of the Hudson Highlands and the southwest spur of the Housatonic Highlands. Any correlation of the rocks on the southeast side of the Highland axis will depend on the structural evidence of this area, as much as on any other evidence, because here for once the pre-Cambrian axis subsides, and sedimentary rocks extend uninterrupted from one side of the Highlands over to the other side. This area was studied in detail because it affords unusually interesting problems, such as the mutual relations between folding, thrusting, development of cleavage, flow lines, contact metamorphism, pegmatite and granite injections, and many others. Some of the petrological problems encountered in the mica schist have recently been discussed by E. B. Knopf[7] and W. M. Agar.[8] Since metamorphic rocks of strikingly similar lithology and identical sequence are known from New Jersey, Pennsylvania and Maryland, the evidence furnished by the area under discussion is likely to be of general importance.

It will be most convenient for the reader if the structural conditions are described from northwest to southeast, because in this direction the complications increase.

1. *Structure Northwest of the Highland Axis.*—Most of the rolling country northwest of the Highlands is underlain by the Hudson River slate, a black or olive-gray argillaceous rock, virtually devoid of key beds, except for some ill-defined zones with conglomeratic, arkosic or graywacke lenses. To the east, the slate grades insensibly into a lustrous phyllite in which the empty holes of limonitized pyrite cubes are seen,

as well as thousands of quartz or quartz-calcite veins. To the eastward of a north-northeast zone which passes through Clove Mountain (west of Clove Valley), porphyroblasts (encarsioblasts) of biotite are found.

In most exposures, the original beds are distinguishable from secondary cleavage, revealing a system of isoclinal folds, slightly overturned to the west or northwest. The axes of these folds pitch to the northeast at fairly gentle angles. In individual ledges, pitching anticlines and synclines from fractions of an inch to over 30 feet in length can be seen, but since continuous large ledges are lacking it cannot be definitely decided whether there are larger anticlines and synclines superposed on the smaller ones.

West of Poughquag, the slate-phyllite belt approaches the Hudson Highlands. Between the two formations there emerges the limestone which, at the old Clove Valley station, has furnished Ophileta, attesting to its early Paleozoic age.[9] The southeast border of the limestone belt rests on the Highland gneisses, flanked by the Poughquag quartzite. Just southeast of Poughquag, there are several ledges showing excellently the unconformity between the quartzite and the gneisses. One is some 1200 feet southeast of the railroad cut described by Dana in 1872; another one is half a mile farther north. The contact there is similar to that described by Gordon from Matteawan:[10] Between distinctly foliated granite gneiss and distinctly stratified quartzite, there intervenes a compact zone, 2 to 5 feet thick, made up of quartz, feldspar, some muscovite and a little magnetite, which in all probability represents a recemented horizon of residual arkose which was incorporated by the advancing Cambrian sea. *The lowest stratification plane lies horizontal, while the underlying granite gneiss dips at 75° to 85° to the east.* Three miles to the south, the unconformity is seen on the west side of Whaley Lake (Clove quadr.), and the same quartzite belt is traversed by pegmatitic dikes with sparingly scattered feldspar crystals south of the road Pawling-Stonehouse.

The phyllite which approaches Clove Valley from the west apparently overlies the limestone both at the north and southwest end of the valley. While the phyllite beds form a gentle anticline on the north, they are compressed into a badly deformed syncline at the southwest end; between the two extreme points, limestone appears in places above the phyllite, either thrust over it along an eastward dipping plane, or as the top of an anticline overturned to the west. At other places, the phyllite ends abruptly in a horizontal position, and the limestone seems to underlie it but is not now exposed, although the records of the old limonite mines clearly establish this relation.

As figure 1 shows, the Clove Valley limestone does not terminate the phyllite. Skirting the north end of the limestone, it expands both to the north and south, constituting a long belt whose southern branch ends near Towners, while the northern branch extends into the Taconic Moun-

tains, well beyond the boundary of the map. This schist belt, then, lies east of the Hudson block, but to the west of the Housatonic block, also to the west of a small pre-Cambrian thrust block north of Pawling, and of a still smaller one east-southeast of Patterson. In this interesting area, there are developed, on top of each other, two systems of rocks whose trend diverges as much as 90° in places, although this discrepancy is greatly obscured in the field.

2. *Structure between the Hudson and Housatonic Highlands.*—The phyllite of this long and wide belt rapidly changes into a schist in which, from west to east, porphyroblasts of biotite, garnet, staurolite, tourmaline and magnetite appear, increasing eastward both in size and relative proportion in the rock.[11] In the hills immediately east of Clove Valley, where these porphyroblasts make their appearance, it was noted that the distribution of the crystals depends on the composition of individual layers. Relatively siliceous layers tend to be richer in garnet and sericite but poorer in biotite than black argillaceous layers. And where quartz veins of appreciable size traverse the rock, they are often surrounded by a zone, 2 to 10 inches wide, in which more and larger porphyroblasts lie than in the more distant portions of the rock. As is known for some time, the eastern half of this phyllite-schist belt consists predominantly of quartz-sericite schist, with or without chlorite, and locally develops staurolite crystals in abundance. In ledges along the central zone, quartz-sericite schist and black biotite schist occur in parallel layers side by side. Transition layers contain both varieties of mica and are relatively rich in garnet. Diaphthoritic chloritization of garnets which has been described by E. B. Knopf[12] from other localities, was not noted here.

Among the quartz veins in this phyllite-schist belt, there are a few which carry feldspar, as well as large crystals of muscovite and tourmaline, indicating an igneous source of most of the quartz veins, and giving a clue to the character of the metamorphism in this zone. Regular pegmatite masses are well developed in the southern half of the belt which flanks the Hudson block on the east.

The internal structure of the rock undergoes a corresponding change from west to east. While moderately appressed isoclinal folds are the dominant structure west and north of Clove Valley, they are rivaled in importance, to the east of Clove Valley, by secondary glide planes which have acted as the principal bearers of all deforming movements subsequent to the main period of folding.[13] It would seem as if several processes have been at work in this schist belt, counteracting one another. Due to compressive forces, the phyllite tended to develop intense cleavage and shear planes, oriented in accordance with the locally acting maximum shear; while the same rock, due to the contact with mineralizers, tended to develop porphyroblasts and coarser grain, rendering the rock less

flexible and mechanically more resistant. The result is most interesting: Where the limbs of the older folds happen to be suitably oriented, they remain in existence, acting henceforth as glide planes. But where they are unfavorably oriented—either in locally deflected areas, or in apices of folds, or along original unconformities—they have been completely blotted out by new systems of favorably oriented shear planes. Since these shear planes happened to develop during a period of anamorphism, the mineral fragments assembling along them have recrystallized, giving rise to new layers ("foliation") which show sufficient difference in texture and composition to simulate original beds.[14] Especially clean and large rock surfaces are necessary to show the divergence between the two. A very good exposure of this kind is at the Club House of the Bald Mountain Hunting Club, along the north-south road, one mile due west of Sharparoon Pond (Clove quadrangle); see figure 2. Long and straight layers of garnet and biotite, which no one would ordinarily hesitate to regard as the original beds, cut clear across the apex of isoclinal folds whose layers are far less conspicuous than the secondary glide planes. They follow each other in distances of a third to one-half of an inch, and along every intersection the older beds are displaced. Where the limbs of the folds happen to strike and dip parallel with the glide planes, both coincide. But the porphyroblasts of biotite and garnet have been developed predominantly along secondary glide planes.

FIGURE 2

Ledge of quartz-sericite schist, on the north-south road, one mile due west of Sharparoon Pond, Clove quadrangle, N. Y. A system of isoclinal folds is dissected and displaced by subparallel shear planes of steep westward dip. Porphyroblasts of garnet and biotite are crowded along these shear planes. In the eastern portions of the schist belt, the foliation is largely due to such recrystallized shear planes which may, or may not, coincide with the limbs of older folds, although they resemble the original beds by their differences in texture and composition. Area 15 by 6 feet.

It is a well-established fact that in the vicinity of a contact, secondary shear planes orient themselves subparallel to the nearest surface which

acts as a mechanical resistance to the general movement.[15] It is unavoidable, therefore, that all contacts between foliated phases of the sediments and the pre-Cambrian gneisses must be "conformable," provided the foliation within the gneiss block runs parallel to the contact (the most common condition in nature). It is difficult to understand how the change from unconformable to conformable contacts could impress some observers so much that they questioned the identity of the two rock units on this account. Not only is such a change a common feature in highly folded rocks, but the basal quartzite repeatedly shows all stages in the obliteration of the original unconformity, as is set forth in the next paragraph. It is unfortunate, however, that the region under discussion, in which the mutual relations between the original bedding and the secondary foliation planes are so well exhibited, has hardly ever been visited by geologists. The correlation problem was attacked from two extreme sides only: from the northwest, where the sediments are not metamorphosed, and from the far southeast, where they are extremely metamorphosed. So long as the intervening sections were not examined, the contrast needs appeared unbridged.

The relations between the pre-Cambrian and Paleozoic rocks are especially well exhibited along the western and southern flank of the Housatonic Highlands. Walking along the basal quartzite west of the gneiss block, one can see repeatedly how the original unconformity, still preserved in three or four localities along the contact, is destroyed by the development of shear planes and cleavage planes in such abundance that the original beds of quartzite cannot be recognized any longer. The secondary planes dip steeply to the east, parallel to the contact with the gneiss, while the quartzite, as a whole, dips at intermediate angles to the west. In a few places it can be seen that the gneiss itself has developed a secondary foliation parallel to the contact. Thus, the two adjoining rocks coöperate in obliterating the original contact relations. The gneiss is pushed at a high angle upward to the west, and there can be little doubt but that this upward motion of the underlying gneiss has caused the transformation in structure in this particular section. The contact between quartzite and gneiss is completely recrystallized, and specimens across the boundary can be obtained without difficulty.

Along the southern termination of the gneiss, the unconformity is preserved on a larger scale; see figure 3. While the foliation in the disappearing gneiss dips steeply to the east, high crags and ridges of quartzite north and northwest of Webatuck show the younger rock to dip gently (10° to 35°) to the south, and the unconformable boundary plane is visible at numerous points. Pegmatitic veins, nevertheless, traverse this rock, and a short distance above the contact the quartzite shows the effects of tremendous deformation: cleavage planes dissect the original beds, crush

zones displace them in short distances, isoclinal folds of astonishing dimensions and sweep have wrought havoc in the higher portions of this brittle and resistant rock. No observer can fail to be impressed to see, in the face of such extreme deformation, the original unconformity still preserved here and there. It is a record of inestimable value for the discrimination and evaluation of older and later periods of orogeny in this region. As Berkey observes,[16] there must have been present a very considerable load of rocks

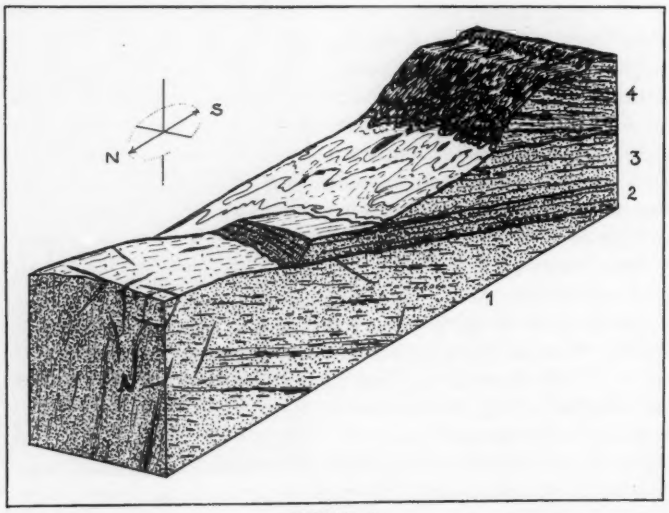

FIGURE 3

Block diagram of the southern termination of the Housatonic Highlands. The pre-Cambrian orthogneiss (1) plunges gently to the south; foliation dips steeply to the east. On its southern slope, the Poughquag quartzite (2) rests with an unconformity of 80 degrees. The quartzite is overlain conformably by the Cambro-Ordovician marble (3) and the schist (4). These two incompetent rocks are isoclinally folded to such an extent that the limbs bear no direct relation to the strike and dip of the quartzite; see figure 4.

superposed to the now visible rocks to allow such extreme folding and deformation. This point will be taken up briefly below.

The quartzite is followed by crystalline marble on the south. A reconnaissance trip through this rock will fail to show any relation between the structure of the marble and the quartzite. The same is true for the ridge of schist which follows farther south (Tenmile Hill). But as soon as the axes of folds in these three rocks are measured, the structural conformity between all three formations is obvious. Because they are relatively incompetent rocks, the marble and schist have been folded into

closely appressed synclines and anticlines whose limbs are drawn out to such an extreme that the first impression is that the marble and the schist strike north-south, and dip steeply to the east, at right angles to the quartzite; see figures 3 and 4. But the axes in all three rocks pitch persistently to the south (with local deviations to the southeast), and the actual trend, both of the marble and the schist, is east-west, the actual dip being gently to the south, parallel to the quartzite. That this is correct is borne out, among other facts, by the appearance, within the schist belt, of disrupted fragments of graywacke. While they are surrounded by foliation planes of the schist which dip at 80° to the east, the stratification, still preserved in the graywacke, strikes east-west; see figure 4. Such an exposure is at the little knoll 840, $1^1/_6$ mile south of "W" of Webatuck (Clove quadrangle), just south of the road.

Between the two principal tracts of schist lies Harlem Valley (or Dover-Pawling Valley), underlain by marble. Dana[17] and E. B. Knopf[18] have noted that the schist west of the valley dips eastward, and concluded that this schist underlies the marble. Although this is technically correct, it does not invalidate the stratigraphic sequence. As was pointed out on page 621, secondary glide planes with steep eastward dip rival with the older limbs of folds in this easterly area. It is a common feature that the actual contact between the two formations is a thrust plane (of fairly moderate throw, however), and specially favorable sections must be visited to recognize the origin of these disturbances from apices of folds, overturned to the west. In such places, the normal sequence, schist above marble, is preserved. Marble underlies the schist, for instance, at the northeast end of the detached ridge south of Sharparoon Pond (Clove quadrangle), and marble reappears, as the core of an anticlinal structure, between Bald Mountain and Dennis Hill, in the heart of the schist belt, and at several other points. This particular topic will not be pursued here because it calls for too many cross sections. The interesting structural relations of the schist inliers in the marble belt, the internal structure of the Highland gneisses, the structural unconformity between the Hudson spur and the schist belt east of it, the overthrusts at Towners and Patterson, the significance of hundreds of amphibolite lenses east and southeast of Pawling, and many other points will be discussed in the forthcoming paper.

3. *Structure Southeast of the Highland Gneisses.*—As is seen in figure 1, the large pre-Cambrian block to which the Highlands belong, breaks down, on the southeast, along a zone of east-west to northeast-southwesterly trend. Beyond this zone, several long but narrow detached blocks of gneiss are seen; it is hard to say whether they still retain their connection with the principal mass, because large portions of the region in question are covered by glacial drift. Peculiar, and of structural significance, is the

semicircular curvature of some of these blocks. The boundaries of the gneiss blocks are steep, often perpendicular. The Paleozoic sediments wrap around the flanks of these gneiss blocks in complete conformity with their irregular boundaries. If the sediments could be removed, huge plates of gneiss would remain standing, with vertical or steeply inclined surfaces; between them, abysses would gape, leading into great depths of the earth's crust. It is certain that the blocks of gneiss have arisen some distance up, because along their flanks the cataclastic lines of stretching point in very steep directions. And the younger rocks, jammed in between these powerful blocks, have not only been rendered extremely plastic so that all vestiges of formerly existing unconformities were obliterated, but the basal quartzite itself has been shorn off its base, and the level of former contact has been raised far beyond the now exposed level of the earth's surface. It is only along a few isolated points, often described in the geology of greater New York, that fragments of the quartzite still remain visible, but here, of course, conformable with the gneiss. It would be unthinkable that an original unconformity should outlast such extraordinary deformation of the crust. Over most of the southeasterly area, the gneiss is in dynamical contact with the marble, or with the schist.

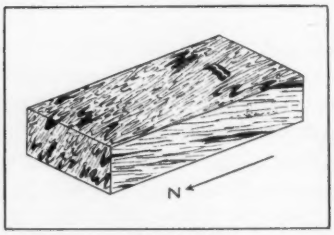

FIGURE 4

Illustrating the relation between observed strike and actual trend of tightly folded incompetent beds. The observed strike is north-south, the actual trend of the rock, as shown by more competent beds (black), is east-west. All details are observed in the schist belt south of the Housatonic Highlands. The axes of folds pitch uniformly to the south at gentle angles.

As will be seen in figure 1, there still remains a certain structural independence between the general east-west trend of the gneiss and the north-south trend of the marble-schist belt along the eastern margin of the map. Even in the highly disturbed southeasterly region, the same independence between pre-Cambrian and Paleozoic rocks is noticeable in the field. The divergence in strike can, of course, never be seen along the actual contact planes, because here both groups of rocks have been drawn out jointly, and in identical directions. Only the cores of the largest rock units have been able to preserve through the later periods of compression and shear, older structures of independent directions in some places, comparable to the rotated tracts of inclusions in garnet porphyroblasts, on a gigantic scale.

Paleozoic Igneous Rocks.—With the Paleozoic age of the marble-schist series well confirmed, the lower age limit of those igneous rocks which

are intruded into them is raised. The various kinds of rocks have often been described by Merrill, Julien, Berkey, Ries, Fettke, Koeberlin, Luquer, Dana, G. H. Williams, Kemp and G. S. Rogers. An older group of serpentines and noritic gabbros is followed by granites with an extraordinary development of pegmatites. Wherever the writer has examined the metamorphic sediments, there is found a close relationship between the degree of metamorphism and the distribution and number of pegmatites. And while some of the basic rocks appear to have been intruded simultaneously with the period of principal folding and shear, there is good evidence that most of the pegmatites, as well as a fine-grained light gray two-mica granite, have arrived somewhat later. These latest rocks have followed in many places shear or thrust planes without being themselves noticeably deformed. Certain augen-gneisses[19] and dioritic gneisses with feldspar augen, like those of Bethel, Connecticut or Peach Lake (Carmel quadrangle), are perhaps of intermediate age. Although there is a remote possibility (not entertained by the present writer) that the marble and schist are of early Cambrian age, it is certain that a considerable column of younger rocks has overlain the three sedimentary formations when they were caught between the rising blocks of gneiss, and permeated by pegmatites. If it is assumed that the schist is of Ordovician age, one would have to assume a column of Silurian or even Devonian rocks on top of it. The writer is not aware of any fact that would discredit such an assumption. The unconformity between the Silurian and Devonian at Rondout and other places in the Catskill region, recently revisited by Schuchert and Longwell,[20] is about 30 miles from the most westerly traces of pegmatites in the Hudson River schist. Moreover, the indications are that the post-Hudson River intrusions have not reached the northwestern part of the pre-Cambrian gneisses; on the contrary, the latter appear to have acted as an effective bulwark against these later intrusions. This, in the writer's opinion, explains satisfactorily the contrast between the little metamorphic Peekskill phyllite, north of the town, which is completely enclosed and protected by pre-Cambrian gneisses, and the more highly metamorphic series southeast, which forms the floor of the funnel of the Cortlandt norite.[21] It stands to reason that the entrapped sediments were permeated by pegmatitic emanations in proportion as the pre-Cambrian basement complex was shattered and faulted. Pegmatites have apparently favored the boundary zones between the older and younger rocks. They are extraordinarily developed in the Croton Falls hornblendite,[22] and in the marble-gneiss belt southeast and south of North Salem (Carmel quadrangle). In the vicinity of Katonah and Goldens Bridge, the pegmatites are joined by a fine-grained two-mica granite which has been correlated with the Thomaston granite in Connecticut by Fettke.[23] It bears strong resemblance to the later Paleozoic granites of Vermont.

Because of the high degree of metamorphism, it is not probable that the igneous rocks southeast of the Highlands have been intruded during the Taconian Revolution. And, as Schuchert and Longwell have stated recently,[24] there is considerable uncertainty as to which one of the two later orogenies (mid-Devonian and late-Carboniferous), and to which extent each one of them have been responsible for the deformation, metamorphism and intrusions in southeastern New York and New England. There are a few facts, however, which, in the writer's opinion, may help to diminish this uncertainty:

1. Lower Devonian fossils are known from highly disturbed rocks in western Vermont.[25]

2. Metamorphic lower Devonian rocks are known for some time from western Massachusetts.[26]

3. Carboniferous plant-bearing phyllites, probably of Pottsville age, at Worcester, Mass., are intruded by gneissoid granite.[27]

4. A series of phyllites, very probably synchronous with the Worcester phyllite, are intruded by pegmatites and gneissoid granite, some eight miles north of Worcester, and their structure indicates a fairly deep level of erosion.[28]

5. One mile due east of Woodcock Hill, Schunemunk quadrangle, New York, a block of pre-Cambrian gneiss is thrust into the Bellvale sandstone of upper Devonian age.[29] Thrust blocks northwest of the Highlands of the Hudson are in line with this same group of thrust blocks which have disturbed the upper Devonian rocks of the Schunemunk area.

In the absence of continuous exposures of late Paleozoic sediments in the southeastern portion of the Appalachian Mountains, the igneous rocks in this part of the mountain belt seem to furnish the most reliable information. And it seems highly probable that future structural studies in the geology of the younger granites in New England will bring about dependable results. As far as the writer can see, the balance of evidence at present seems to emphasize the importance of the latest Paleozoic revolution rather than the earlier ones. Arthur Keith has pointed this out repeatedly.

[1] Dana, J. D., *Am. J. Sci.* (3) **3**, 250–256 (1872); **13**, 332–347, 405–419, (1877); **17**, 375–388 (1879); **20**, 21–32, 194–220, 359–375, 450–456; **21**, 425–443 (1880); **22**, 103–119, 313–315, 327–335 (1881); **40**, 256–257 (1890).

[2] Merrill, F. J. H., "On the Metamorphic Strata of Southeastern New York," *Am. J. Sci.* (3) **39**, 383–392 (1890); "The Geology of the Crystalline Rocks of Southeastern New York," *N. Y. State Mus. Ann. Rep.*, 50, **1**, 21–31 (1898); *U. S. G. S. New York City Folio*, No. **83**, 3–5 (1902); "Description of the State Geologic Map of 1901," *N. Y. State Mus. Bull.*, **56**, 3–37 (1902). Brief notes also in *N. Y. State Mus. Ann. Rep.*, *54*, *55* and *56* (1902–1904).

[3] Mather, W. W., *Geology of New York*, part 1, 653 pp., Albany, N. Y. (1843).

[4] Berkey, C. P., "Structural and Stratigraphic Features of the Basal Gneisses of the Highlands," *N. Y. State Mus. Bull.*, **107**, 361–378 (1907).

[5] Berkey, C. P., and Rice, M., "Geology of the West Point Quadrangle," *N. Y. State Mus. Bull.*, **225–226** (1919).

[6] Johnson, D., *Stream Sculpture on the Atlantic Slope*, Columbia University Press, p. 53 (1931).

[7] Knopf, E. B., "Retrogressive Metamorphism and Phyllonitization," *Am. J. Sci.*, **21**, 1–27 (1931); "Some Results of Recent Work in the Southern Taconic Area," *Am. J. Sci.*, **14**, 429–458 (1927).

[8] Agar, W. M., "The Quartzite of Rattlesnake Hill, North Canaan, Conn.," *Am. J. Sci.*, **21**, 409–421 (1931); "The Petrology and Structure of the Salisbury-Canaan District of Connecticut," *Am. J. Sci.*, **23**, 31–48 (1932).

[9] Dwight, W. B., *Am. J. Sci.*, **39**, 71 (1890).

[10] Gordon, C. E., "Geology of the Poughkeepsie Quadrangle," *N. Y. State Mus. Bull.*, **148**, 46 (1911).

[11] Fettke, C. R., "The Manhattan Schist of Southeastern New York State and Its Associated Igneous Rocks," *Ann. N. Y. Ac. Sci.*, **23**, 249–251 (1914).

[12] Knopf, E. B., 1931, p. 21.

[13] The phyllite-schist belt which surrounds Clove Valley affords magnificent examples of "Umfaltungs-cleavage" (E. B. Knopf, 1931, p. 16–18), and the writer fully agrees with E. B. Knopf that this imbricate structure is one of the principal characteristics of the schist belt. However, the amount of throw along each individual glide plane seems to have been very small, and the writer is not aware of any thrust in this zone that has moved one part of it a long distance over another part.

[14] The relation between folding and subsequent shredding of the rock into a multitude of sheets bordered by shear planes is in every detail identical with the conditions described recently from Germany (Scholtz, H., "Faltung und Schieferung im Ostsauerländer Hauptsattel," *Centr. Blatt f. Min.*, Abt. B, No. **7**, 321–335 (1932); "Über das Alter der Schieferung und ihr Verhältnis zur Faltung," *Jahrb. d. Pr. Geol. L. A.*, **52**, 303–316 (1931); "Das Varistische Bewegungsbild," *Fortschr. d. Geol. & Pal.*, **8**, No. 25, 82 pp., Berlin., Gebr. Borntraeger (1930)). But while the rocks in the German mountains rarely attain the metamorphic rank of phyllites, the anamorphism in the region under discussion has advanced much farther.

[15] See, for instance, the upper profile in plate 7, in Scholtz, 1930.

[16] Berkey, C. P., 1919, p. 138.

[17] Dana, J. D., 1872, p. 251.

[18] Knopf, E. B., 1927, p. 446.

[19] Barbour, G. P., "Origin of the Bedford Augen-Gneiss," *Am. J. Sci.* (5) **19**, 351–358 (1930).

[20] Schuchert, C., and Longwell, C. R., "Paleozoic Deformations of the Hudson Valley Region," *Am. J. Sci.*, **23**, 305–326 (1932).

[21] Balk, R., *Neues Jahrb. Mineral., Geol., Beilage Bd.*, **52**, Abt. B, 249–303 (1927). It may be observed in this connection that the schist which outcrops northwest of Crugers Station (Tarrytown quadr.) grades, within less than 250 feet, into a finely laminated quartz-phyllite. The phyllite rests on the limestone, while the coarse-grained garnetiferous schist is intensely injected by quartz veins and pegmatite lenses, serving as the floor of the norite. This gradation was known to Dana (*Am. J. Sci.*, **22**, 2 (1881)). Fettke also describes phyllitic phases of the schist from Croton Village (op. cit., 206–207). They appear in the vicinity of the Cortlandt norite. Similar phyllitic rocks outcrop in new road cuts east of Peekskill, underlying the norite on the north. It is not unlikely that the norite intrusion, characterized by relative scarcity of mineralizers, has preserved, at some points along its contact zone, phyllitic rocks, not much different from those which outcrop north of Peekskill.

[22] Fettke, C. R., op. cit., 231; Koeberlin, F. R., "The Brewster Iron-Bearing District of New York," *Econ. Geol.*, **4**, 737 (1909).

[23] Fettke, C. R., op. cit., 234.

[24] Schuchert, C., and Longwell, C. R., op. cit., 321–324.

[25] Schuchert, C., and Longwell, C. R., op. cit., 321.

[26] Emerson, B. K., *U. S. G. S. Bull.*, **597**, 48–49 (1917); Emerson, B. K., *U. S. G. S. Mon.*, **29**, 252–299 (1898).

[27] White, D., "Age of the Worcester Phyllite," *Wash. Acad. Sci. Jour.*, **2**, 114–118 (1912).

[28] Callaghan, E., "A Contribution to the Structural Geology of Central Massachusetts," *N. Y. Acad. Sci. Ann.*, **33**, 27–75 (1931).

[29] Oral communication of Miss Helen Hoppe.

CHROMOSOME RINGS IN OENOTHERA, DROSOPHILA AND MAIZE

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Communicated August 17, 1932

In a recent issue of this Journal, Brink and Cooper[1] have postulated inverted sections in the ring chromosomes of Oenothera to account for the small amount of crossing-over observed in certain hybrids. Their hypothesis is similar to that previously advanced by Darlington[2] which differs chiefly in supposing that there are "differential segments" in the ring chromosomes instead of inverted sections. Brink and Cooper have further suggested that these inverted sections may be responsible for the more regular disjunction of chromosomes in Oenothera than in maize. The purpose of the present note is to call attention to certain genetic data already in print which are not in agreement with the interpretations advanced by Darlington and by Brink and Cooper.

In the first place, there is little or no evidence that crossing-over in Oenothera is much less in ring chromosomes than in paired chromosomes. The majority of all linked genes so far studied show very little crossing-over even in paired chromosomes. So far only two linkage groups have been studied extensively: *R-v-bu-sp* group in chromosome 1·2 and the *P-n-s* group in chromosome 3·4. Shull[3] has found very little crossing-over between *v*, *bu* and *sp* in his *Oe. Lamarckiana* crosses in which chromosome 1·2 was presumably a paired chromosome. Sturtevant[4] has found little crossing-over between *R* and *v* in crosses in which these genes were known to be in a pairing chromosome. In crosses in which chromosome 3·4 was known to be a paired chromosome, I have recovered no crossovers between *s* and *n* in F_2 generations[5] but have found about 8 per cent crossing-over be-

tween *P* and *s* (in backcrosses to the double recessive). When chromosome 3·4 was in a ring of 10 (*sulfurens*.^{h}*franciscana*), there was about 5 per cent crossing-over between *P* and *s*,[6] which is nearly the same as that observed in paired chromosomes. The linkage between *R* and *P* in *flavens*·*velans* discussed by Brink and Cooper involves genes lying in different chromosomes (1·2 and 3·4) in one of the rings of 4. Perhaps the simplest interpretation of the scarcity of crossovers in this case is that both genes lie near the translocation points. Studies on Drosophila show that crossing-over is strongly reduced near the translocation point and a similar reduction is to be expected in Oenothera and in maize. In contrast to the genes already discussed there are two in Oenothera (Co, flower size,[7] and br, brevistylis) which give about 50 per cent crossing-over with all other genes regardless of the association of chromosomes in rings. The loci of Co and Br and apparently near the end of one chromosome with about 15 per cent crossing-over between them.[4] It can be seen that there is no evidence that crossing-over is reduced in the ring chromosomes of Oenothera, and until there is such evidence it seems hardly necessary to postulate causes of the purely hypothetical reduction.

Darlington[2] has assumed that most of the genes by which Oenothera complexes differ lie in the mid regions of the chromosomes and that these regions have their homologs not in the adjoining chromosomes but in chromosomes more distant in the ring or in other rings or pairs. (At least that is what I believe Darlington means by "differential segments.") If this were the true condition, then the occasional crossovers which do occur should alter the chromosome configuration in the crossover individual since there would be a new association of ends in the crossover chromosomes. None of the published cases of crossing-over in rings has given a changed configuration. Among the reported cases are the occasional appearances of sulfur-flowered individuals among the progeny of *Oenothera biennis* and *Oe. suaveolens* and of nanella among the progeny of *Oe. Lamarckiana* and *Oe. biennis*. Cleland[8] has found that the sulfur-flowered races have the same configurations as their parental forms and Sturtevant[9] found that a nanella plant appearing in his culture of *Lamarckiana* had the same configuration as its sibs. In the crossovers occurring in rings in my cultures[4,6] all crossover individuals examined had the same configurations as their immediate parents. From these examples one is justified in concluding that most of the genes so far studied do not lie in sections of the chromosomes that are not homologous to corresponding sections in adjoining chromosomes. That such "differential segments" do occur, however, is to be expected in such forms as Oenothera where translocations are so abundant, but such sections could hardly be expected to contain all the genes by which complexes differ as postulated by Darlington.

Brink and Cooper's recourse to inverted sections to account for the

regular disjunction of ring chromosomes in Oenothera is perhaps equally unavailing. Dobzhansky and Sturtevant[10] have found that the frequencies of the different types of disjunction of ring chromosomes vary from one translocation to another in Drosophila when no inverted sections are present. Furthermore, unless the inverted sections always involved only the spindle fibre regions, the presence of inverted sections would reduce the Oenothera type of disjunction and cause the chromosomes to be segregated more nearly at random.

It would seem, from our present understanding of Oenothera genetics, that it is not only unnecessary to postulate inverted section or "differential segments" in the ring chromosomes to explain certain Oenothera peculiarities, but also that such interpretations are not in agreement with the known genetic behavior of this plant.

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